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WATER RESOURCES INVESTIGATION

CONNECTICUT RIVER BASIN

EAST HARTFORD LOCAL PROTECTION

MODIFICATION STUDY

STAGE 2 REPORT

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

CONNECTICUT RIVER BASIN

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PREFACE

This Stage 2 report is presented to provide documentation of the methodology, rationale and technical back-up to support the formulation, assessment and evaluation of alternative plans for the modification of the existing East Hartford, Local Protection Project. The need and advisability of increasing the degree of flood protection for the highly developed center of East Hartford will be presented.

In seeking solutions to the flood control needs of the town of East Hartford, consideration has been given to the objectives of National Economic Development and Environmental Quality as well as Regional Development and Social Well-Being of the people. All significant adverse and beneficial project effects on the environment, including the aesthetics of the area, have been identified and assessed and the feasibility of eliminating or minimizing adverse effects have been explored.

The East Hartford Local Protection-Modification study is a feasibility study of survey scope referenced by the Water Resources Council as Level C. The study has incorporated information from previous studies of the Connecticut River Basin at East Hartford. Other water resources needs and comments on the proposed alternative solutions have been solicited at public meetings and through coordination with various Federal and State agencies as well as local interests.

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THE STUDY AND REPORT

PURPOSE AND AUTHORITY

The purpose of the study is to determine the feasibility of modifying the existing flood control system in East Hartford, Connecticut. The purpose of this Stage 2 report is to report on the progress of the study since completion of the Plan of Study in July 1977. Since completion of the Plan of Study alternative plans for modifying the existing local Protection Project have been formulated following the multiobjective planning framework of the WRC Principles and Standards, the National Environmental Policy Act of 1969 and related policies.

In order to fully understand the objective of modifying the existing Local Protection project it is important to present the background of the flood problems in East Hartford and the preceding authorizations.

Since its founding in the seventeenth century the Town of East Hartford has been subject to periodic flooding from the Connecticut and Hockanum Rivers. The greatest floods for which reliable records exist occurred in March 1936, September 1938, and August 1955.

Realizing the severity of the flooding problem the 69th Congress (First Session) passed House Document No. 308 on 21 January 1927, which directed the Corps of Engineers to conduct a flood control study of the Connecticut River. A report, which took the name "308 Report", dated 11 Februrary 1936, was submitted to Congress with the recommendation that ten flood control reservoirs be built on the tributaries of the Connecticut River in Vermont and New Hampshire. This report was the basis for the 1936 Flood Control Act which established a Federal interest in flood control.

Ironically, one month after the "308 Report" was submitted to Congress, the Connecticut River Basin experienced the disasterous flood of March 1936. As a result of this flood another study was made and reported in March 1937. This report provided for the first general comprehensive plan for flood control for the basin and included twenty reservoirs, with ten alternative reservoirs, and most important, seven local protection projects at Hartford, East Hartford, Springfield, West Springfield, Chicopee, Holyoke, and Northampton. This comprehensive plan was approved in the 1938 Flood Control Act.

There have been numerous modifications to the basic flood control plan over the years, but presently the Corps of Engineers has constructed a total of sixteen dams and all seven of the original local protection projects in the basin.

Existing flood control structures in the basin are discussed in more detail in the 1970 report: "Connecticut River Basin Comprehensive Water and Related Land Resources Investigation", Volume VIII, (reference 3).

The authority for the current study is contained in a resolution of the Committee on Public Works of the United States Senate adopted 11 May 1962, which recommended a review of existing reports in the Connecticut River Basin. The resolution was as follows:

> "That the Board of Engineers for Rivers and Harbors, created under section 3 of the River and Harbor Act, approved June 12, 1902, be, and is hereby, requested to review the reports on the Connecticut River, Mass., New Hampshire, Vermont and Connecticut, published as House Document Numbered 455, Seventy-Fifth Congress, second session, and other reports, with a view to determining the advisability of modifying

the existing project at the present time, with particular reference to developing a comprehensive plan of improvement for the basin in the interest of flood control, navigation, hydroelectric power development, water supply, and other purposes, coordinated with related land resources."

A seven year Federal-State study effort resulted in a report entitled "Comprehensive Water and Related Land Resources Investigation", dated June, 1970. The coordinating committee which guided this study recommended a 1980 basin plan which included the construction of additional flood control reservoirs to supplement the existing sixteen reservoirs and seven mainstem local protection projects (including East Hartford). Since 1970, the basin States have withdrawn support of the plan, consequently, the New England River Basins Commission (NERBC) chaired a supplemental flood control study of the Connecticut River Basin. The resulting report, "The River's Reach" dated December 1976, includes recommendations to study methods of reducing the possibility of overtopping by raising the existing dikes and floodwalls in East Hartford, Springfield, West Springfield, Chicopee, Holyoke, and Northampton in lieu of the seven additional flood control dams recommended in the 1970 Connecticut River Basin (CRB) report. Other recommendations include construction of small dams and dikes where economic, environmental and social impacts and local cost sharing are acceptable and the utilization of effective non-structural solutions to flood plain management problems wherever possible.

SCOPE OF THE STUDY

This study was undertaken to investigate alternative methods of increasing the degree of flood protection for East Hartford. Levels of protection provided by the existing facilities were determined and current and future potential for flood damages assessed. Alternative damage reduction measures were evaluated with regard to engineering and economic feasiblity and associated environmental impact. Alternative plans suggested by local interests were also investigated and evaluated. Investigations were carried out only to the depth and detail required for a determination of Federal interests.

STUDY PARTICIPANTS AND COORDINATION

Formulation of alternative plans for increasing the flood protection for East Hartford required close coordination with Federal, State and local officials, and interested groups and individuals. The coordination included numerous meetings with those interested in order to insure that all views were included in the plan formulation process.

A general public meeting was held in East Hartford on 31 May 1978 to present alternative plans to meet the objectives of the study. Since the public meeting other smaller meetings have been held including one with a neighborhood group, and others with city officials and the State of Connecticut. The results of the meetings and pertinent correspondence have been integrated throughout the report.

THE REPORT

This report follows the general outline used for final Feasibility Reports except that sections pertaining to a selected plan have been omitted.

PRIOR STUDIES AND REPORTS

This section presents a list of studies and reports related to the current investigation. Descriptions, results and analysis of these studies and reports are presented in other sections of this report.

1. New England Division, U.S. Army Corps of Engineers, "The Report of Survey and Comprehensive Plan for the Connecticut River", dated 20 March 1937.

2. Flood Control Act approved 28 June 1938, House Document No. 455, 75th Congress, 2nd session.

3. New England Division, U.S. Army Corps of Engineers, "Connecticut River Basin - Comprehensive Water and Related Land Resources Investigation", June 1970.

4. New England - New York Inter-Agency Committee, "The Resources of the New England - New York Region", Reference Data, dated March 1955.

5. New England Division, U.S. Army Corps of Engineers, "Review of Reports on Surveys of the Connecticut River and Tributaries for Flood Control", dated 28 Fcbruary 1940, Revised 18 December 1944.

6. New England River Basins Commission, "The River's Reach" - a United Program for Flood Plain Management in the Connecticut River Basin", dated December 1976.

7. New England Division, U.S. Amry Corps of Engineers, "Plan of Study - East Hartford Local Protection Modification Study", dated July 1977.

STUDIES IN PROGRESS

Concurrent with the East Hartford Modification Study is the Connecticut River Basin Flood Plain Management Study authorized under Section 73 of the 1974 Flood Control Act. The study, a national pilot study, is being prepared for a report to Congress on the feasibility and methods of securing Federal funding for non-structural flood plain management.

The study will explore the development of feasible, implementable, flood damage reduction measures for three selected pilot-study areas: Northampton, Mass., Keene, New Hampshire and the Great Meadows area of Connecticut which includes the towns of East Hartford, Wethersfield, Glastonbury and Rocky Hill. The various alternatives considered will be formulated, assessed and evaluated in accordance with established Corps policies and procedures including the Water Resources Council's Principles and Standards for water and related land resources studies. The alternatives as a minimum will include: flood proofing measures, acquisition and relocation, flood warning and evacuation, zoning and building code requirements for areas currently subject to flooding from the Intermediate Regional Flood. From the final array of alternatives a plan will be recommended for implementation.

Close coordination will be maintained during the course of the study to insure that the problems and needs of East Hartford are addressed and that recommendations of the two studies are compatible.

RESOURCES AND ECONOMY OF THE STUDY AREA

ENVIRONMENTAL SETTING AND NATURAL RESOURCES

East Hartford is located on the east bank of the Connecticut River, 52 miles above the mouth of the Connecticut River and directly across from the capital city of Hartford. The Connecticut River Basin shown on Plate 1 is the largest watershed in New England and has a drainage area of 11,250 square miles of which 114 square miles are located in the province of Quebec, Canada. See the Hydrology section of this report for a more detailed description of the Connecticut River basin including Climatology and Stream Characteristics.

Due to its natural setting, the community of East Hartford became a manufacturing center in the early 18th century; the first powder mill in America was built on the Hockanum River, a tributary which meets the Connecticut River at East Hartford. By 1823 a conglomerate of industries including eight powder mills were in operation. The old industries are gone now, but new ones have replaced them. The study area along the Connecticut River is approximately 760 acres of residential, commercial, and industrial property; this valuable real estate is protected by the existing dikes. The natural ecological resources of the area although limited, are of special value because of their proximity to the Connecticut River and the state capital, the city of Hartford.

HUMAN RESOURCES

East Hartford's population during the period from 1930 through 1970 has shown a higher growth rate than both Hartford County and the State, as detailed in Table 1. East Hartford experienced a growth of 30.9% between 1960 ani 1970. A population estimate for 1977 of 58,500 indicates a 2% increase over the 1970 population of 57,583.

The median age of the population in 1970 was 27.6 years as compared with a state median of 29.1. Median income of $11,771 fell below both the County and the State of $12,057 and $11,881 respectively. 3.4% of East Hartford's families were below the poverty level with 26.8% earning more than $15,000.

7.8% of East Hartford's population were foreign born with nearly half of these being of Italian or Canadian heritage. An additional 25.4%

Table 1
Population Statistics

Year	East Hartford	% Change last over period	Hartford County	% Change	Connecticut	% Change
1930	17,125		421,097		1,606,903	
1940	18,615	8.7%	450,189	6.9%	1,709,242	6.4%
1950	29,933	60.8%	539,661	19.7%	2,007,280	17.4%
1960	43,977	62.2%	689,555	29.6%	2,535,234	26.3%
1970	57,583	30.9%	816,737	18.4%	3,032,217	19.6%

Source:
U.S. Census

of the population were of foreign and mixed parentage with over 65 percent of these being of Canadian, Polish or Irish backgrounds.

Of the total of employed persons 16 years old and over in 1970, 26.3% fell in the category of clerical and kindred workers, 16.6% were craftsmen, foremen, and kindred workers, and 16.4% were professional, technical and kindred workers.

ECONOMY

East Hartford, settled in 1635, remained a part of Hartford until 1783. The meadow lands along the Connecticut and Hockanum Rivers offered excellent soil for farming. For its first 200 years, East Hartford remained a peaceful agrarian community, with small manufacturers dotted along its streams.

With the emergence of Hartford as a major commercial center by 1900 the town became primarily a residential suburb. Since 1929, when Pratt and Whitney Aircraft Company chose to locate in East Hartford the town has become a major industrial center. Pratt and Whitney were responsible for the subsequent population influx as well as a determinant in a large segment of the industrial community eventually established within the town. Its principal industries now include the manufacture of aircraft engines, precision parts and steel fabrication. Approximately 14,000 people are employed by Pratt and Whitney in East Hartford.

At the present time, East Hartford hosts about 125 diversified manufacturing plants. Sheet metal fabrication, plastics, welding, printing, manufacture of precisions parts, electroplating, grinding, burring, and tumbling are among many products manufactured by East Hartford firms.

Employment in the manufacturing sector has continued to grow through the last decade. However, the proportion of total employed working in this sector has decreased from 44.1% to 33.8% between 1960 and 1970. Other sectors, especially the wholesale/retail trade and services sectors have experienced a more rapid growth. The recent construction and renovation of two shopping malls totalling approximately 5.1 acres have established East Hartford as a retail center for several of the surrounding communities.

Approximately, 60 percent of the town is zoned for business and industry, thereby creating a plethora of jobs in the immediate vicinity. Altogether, the town contains 950 commercial and industrial structures, and one high-rise office, Founders Plaza. East Hartford was a net importer of labor in 1970, providing employment for 46,930 people while possessing a labor force of 27,829. Employment distribution is detailed in Table 2.

Table 2

Industry of Employed Persons

	1960	1970	Percent Change	Percent of Total 1970
Agriculture	128	178	39.1	0.7
Construction & Mining	867	1,430	64.9	5.23
Manufacturing	8,141	9,214	13.2	33.8
Trans., Comm., Util.	956	1,297	35.7	4.7
Wholesale/Retail Trade	3,043	5,500	80.7	20.2
Fire Insurance, and				
Real Estate	1,914	3,509	83.3	12.9
Services	2,058	4,796	133.0	17.6
Public Administration	705	1,299	84.3	4.8
Not Categorized	660	-	-	-
TOTAL	18,472	27,223	47.4	100.0

Source: U.S. Census

Land Use Characteristics - Approximately 15% of East Hartford's total land area of 12,026 acres is undeveloped. Residential use makes up the largest proportion of the developed land area with over 35% of the town's land being devoted to housing development. Since 1960, the number of dwelling units in East Hartford has increased nearly 50%, although growth since 1970 has increased at a much slower rate than the preceding decade. Current 1976-77 estimates indicated that the housing stock in East Hartford is composed of 10,765 single family dwelling units, 1,141 two family dwelling units, and 6,535 multi-family and mobile home units totalling 19,582 for the town. About 1100 acres of undeveloped zoned residential land are still available for the building of more homes or apartment buildings in East Hartford. During 1975, the town issued 816 building permits, 48 of which were for homes.

At one time Main Street was the major and only retail section in East Hartford. Today, Main Street contains a number of smaller specialty shops. However, shopping centers, skirting the community are drawing customers away from this older retail area.

There are three major shopping centers located within the boundaries of East Hartford; Putnam Bridge Plaza located on Maine Street at the Glastonbury Town Line; Powder Mill Shopping Center located on Burnside

Avenue; and the Charter Oak Shopping Mall. However, because of the rapid growth in town, much of the commercial development is generally linear or "strip development". A retail area along Connecticut Boulevard inhabited by major automobile dealers lies within the portion of East Hartford protected by the present dike system.

For the most part, industrial development has occurred on a scattered site basis. Of the 1256 acres devoted to industrial users, 334 acres lie within three industrial parks. Total available acreage in the three parks is 104 acres. The oldest industrial park is Prestige Industrial Park located on Prestige Park Road. About 24 of the park's original 85 acres remain undeveloped. The Roberts Street Industrial Park is a 229-acre site on the north side of Roberts Street. Opened in 1969, the park contains only about 15 acres of land yet to be developed. A third park, the Burnham Industrial Park is located south of Burnham Street. There are 65 acres of undeveloped industrially zoned land at this site. Land use acreage for all categories is shown in Table 3.

The current dike system protects approximately 760 acres. The area protected is a mix of industrial, residential, and commercial uses. In residential areas the dikes are generally well removed from improved properties except where they tie into high ground. The dikes are most visibly prominent along East River Drive where they border Founder's Plaza, and along the industrial area between Connecticut Boulevard and Cedar Street.

Table 3

1975 Land Use by Category

East Hartford

Land Uses	Acres	Percent of Total
Residential	4,404	36.6
High	1,085	9.0
Medium	3,319	27.6
Low	0	-
Commercial	326	2.7
Industrial	1,256	10.5
Open Area	6	.0
Utilities	720	6.0
Institutional	295	2.5
Recreational	662	5.5
Agriculture	670	5.6
Undeveloped	1,913	15.9
Water	462	3.8
Wetlands	1,312	10.9
TOTAL	12,026	100.0

Future Development - It is expected that new development in East Hartford will be accommodated within the existing land use patterns. General land use policy encourages preservation of open space, wetlands, watercourses and other environmentally sensitive areas; either by regulation or outright acquisition. Maintenance of the natural hydraulic capacity of the flood plains, and preservation of wildlife habitat, open space and agricultural areas in concert with growth and development are recommended policies.

As maturation continues in East Hartford, there will be no major changes in land use patterns. Future development will primarily be the result of infilling and replacement. Most vacant land in East Hartford is scattered in fragmented pieces throughout the town and has remained vacant because of particular restraints such as poor drainage. Most residential development that can be expected to occur will be single family units on small, scattered parcels. It has been estimated that 170 acres are left for commercial development. However because of investment in older commercial areas, revitalization of existing areas seems more likely than development in vacant areas. As with residential and commercial areas, there are very few sizeable parcels of developable land for industrial uses. Although there are three industrial parks which have attempted to organize industrial use, remaining vacant industrial land exists in generally small scattered parcels.

PROBLEMS AND NEEDS

The Connecticut River Basin has experienced numerous floods in the past, several of which have taken the lives of basin residents and brought serious financial burdens to bear upon them. Although much has been done to alleviate the flood hazards in the Connecticut River Basin there is still a significant flood problem in areas such as East Hartford. This section will include descriptions of past flood events, improvement to prevent or reduce damages and some other water resources related problems and needs in the study area.

STATUS OF EXISTING PLANS AND IMPROVEMENTS

The existing East Hartford local protection project was completed in 1943 and provides protection for about 760 acres. The area which is protected by the dikes consists of residential, commercial, industrial and public property in a highly populated section of East Hartford. The protective works consist of approximately 20,000 feet of earth fill dikes and 750 feet of concrete floodwalls. The project also consists of two stop-log structures and three pumping stations for interior drainage. The alignment of the dike and major features are indicated on Plates 5 thru 7.

FLOOD PROBLEMS

Periodic flooding from the Connecticut and Hockanum Rivers has occurred in the Town of East Hartford since its founding in the seventeenth century. The greatest floods for which reliable records exist took place in March 1936, September 1938, and August 1955.

As previously discussed under the heading "Purpose and Authority", the height of protection to be rendered to the town was specified in a general comprehensive plan of flood control for the entire Connecticut River Basin; the plan recommended that twenty reservoirs and ten alternative reservoirs be constructed in the basin upstream of East Hartford. To date, sixteen reservoirs and seven local protection projects have been completed. Although these projects offer a high degree of protection to the flood prone areas they do not provide the protection as specified by the Corps criteria or as authorized by the Congress of the United States. In addition, the townspeople were orignally given the assurance that the project would be designed and constructed in accordance with this criteria.

Flood History - Damaging floods have been experienced on the Connecticut River and its tributaries since the establishment of the first settlements in the basin. Reliable records have been kept of flood stages at Hartford since about 1838.

The greatest flood of record on the lower Connecticut River was experienced in March 1936 when a stage of 37.6 feet (37.0 feet msl) was reached at the Hartford gage. The second greatest flood occurred in September 1938, with a level of 2.2 feet below the 1936 peak stage.

East Hartford is located within the limits of a long storage reach on the Connecticut River; therefore, peak flood stages at East Hartford are more a function of peak storage in the reach rather than peak flow in the river through Hartford. This storage effect creates a hysteresis effect on the rating curve at East Hartford and due to the lack of a constant stage-discharge relationship at East Hartford, the stages at East Hartford are related to peak flows on the river downstream at Middletown, Connecticut where flows are a function of maximum storage in the reach.

Historic flood levels at East Hartford versus peak flows at Middletown, Connecticut are listed in table 4.

TABLE 4

HISTORIC FLOOD LEVELS

HARTFORD, CONNECTICUT

Date	Flood Level at Memorial Bridge (ft msl)	Estimated Discharge at Middletown, Connecticut (cfs)
Mar 1936	37.0	267,500
Sep 1938	34.0	239,000
Aug 1955	30.0	188,000
May 1854	29.2	180,000
Nov 1927	28.4	172,000

OTHER NEEDS

In conjunction with the local protection modification study, other water resource needs were investigated. Needs such as water supply, hydroelectric power generation, and other water related resources were not found applicable to a project of this nature.

Improvements Desired

In a letter dated July 19, 1974 Mayor Richard Blackstone of the town of East Hartford expressed his desire for initiation of a feasibility study to investigate raising the existing dike system. During the course of the study several meetings were held with State and local officials, and private citizens. State and local officials have indicated their support for increasing flood protection to the area. At the 31 May 1978 public meeting the citizens expressed their support for the project but were not in favor of expanding the flood protection into other areas not currently protected by the existing dike system. The local officials reflect the same views of the citizens.

HYDROLOGIC BACKGROUND

This section presents the basic hydrology used in studies of the need and feasibility of modifying the existing Local Protection Project. Included are sections on general description, climatology, streamflow, flood history, design flood development, and the effect of existing reservoirs.

Connecticut River Basin - The Connecticut River rises in the Connecticut Lakes of northern New Hampshire adjacent to the Canadian border. The river follows a general southerly course along the approximate centerline of its watershed for about 404 miles to its mouth on Long Island Sound at Saybrook, Connecticut. The lower 60 miles of the river are tidal, with a mean tidal range during low river stages of 3.4 feet at the mouth, and about 1.2 feet at East Hartford, 52 miles above the mouth. The fall in the river is about 2,200 feet with the steepest portion averaging 30 feet per mile occurring in the first 30 miles below the outlet of Third Connecticut Lake. From Wilder Dam, Vermont to the head of tidewater, eight miles above East Hartford, Connecticut, the fall averages about two feet per mile. The Connecticut River basin, shown on plate 1, has a total drainage area of 11,250 square miles. At East Hartford the Connecticut River drains an area of 10,480 square miles.

HYDROLOGY

General - The basic hydrology presented in this report was taken largely from prior hydrologic engineering studies pertinent to the study area.

Climatology - Central Connecticut has a variable climate characterized by frequent but usually short periods of precipitation. This section lies in the path of the "prevailing westerlies" and is exposed to the cyclonic disturbances that cross the country from the west and southwest toward the northeast quadrant of the country. The area is also exposed to coastal storms, some of tropical origin, that travel up the Atlantic seaboard. Thunderstorms either of a local origin or associated with a frontal system, occur generally during the summer months.

Temperature - Average monthly temperatures in East Hartford vary considerably throughout the year with a mean annual temperature of about 50° Fahrenheit. The summer temperatures average in the upper 60 and low 70 degrees, with winter temperatures averaging in the upper 20 and low 30 degrees. Freezing temperatures can be expected from the middle of November until the end of March.

Precipitation - The average annual precipitation at East Hartford is about 42 inches, distributed rather uniformly throughout the year. Maximum and minimum annual precipitation at the National Weather Service recording station over 67 years of record are 62.9 and 29.4 inches, respectively.

Snowfall and Snow Cover - Based on 66 years of record, snowfall at East Hartford averaged about 44 inches. Water content of the snow cover in the region reaches a maximum depth about the first of March. Maximum snow pack each year varies from zero to 5.4 inches of water equivalent with a mean of 2.4 inches.

Streamflow - The average annual streamflow in the Connecticut River basin is 23 inches or about 53 percent of annual precipitation, representing an average riverflow at East Hartford of about 18,000 cfs. East Hartford is located in the upper end of an extensive natural storage basin and is also affected by tidal fluctuations during normal flow periods. However, records of peak flood stages on the Connecticut River at Hartford which is located directly across the river from East Hartford, have been maintained by the National Weather Service.

HYDROLOGIC ENGINEERING DATA FROM PRIOR STUDIES

Flood Frequencies - Discharge frequency curves for the Connecticut River at Middletown, Connecticut are shown on plate 2. These curves represent natural and modified peak flow frequencies. The natural frequencies are graphical presentations of the data tabulated in table C-10, Appendix C, of the June 1970 Connecticut River Comprehensive Report. Peak discharge frequencies were determined by a regional analysis using a Log Pearson Type III analysis as described in Water Resources Council Bulletin No. 15, entitled: "A Uniform Technique for Determining Floodflow Frequencies".

Effect of Reservoirs - Since the great floods of March 1936 and September 1938, the Corps of Engineers has constructed a system of 16 flood control reservoirs in the Connecticut River basin, which control flood runoff from 1,570 square miles, or 15 percent of the Connecticut River watershed above East Hartford. Typical flood reductions provided by the existing system of reservoirs at East Hartford and Middletown are illustrated by the natural and modified stage and discharge frequency curves shown on plates 2 and 3. It is cautioned that for every occurrence of a certain frequency flood the reduction will not be exactly as indicated by the modified frequency curves. The magnitude of reduction will vary depending on the storm orientation with respect to the upstream reservoirs. The modified frequency curves shown represent the expected average or typical reduction as determined by analyses using the "Typical Tributary Contribution Flood", as developed by the New England Division, Corps of Engineers.

Reductions in discharges and stages that would be provided by the system in the recurrence of the specific 1936 and 1938 historical floods at Hartford are listed in table 5.

Original Design Flood - The East Hartford protective works were designed for a Connecticut River flow at Hartford of 248,000 cfs, which is equivalent to a flow of about 242,000 cfs at Middletown and a design flood stage of 35.0 feet msl at Memorial Bridge in East Hartford. The original 1937 design flood was developed by modifying a natural design flow of 318,000 to 209,000 cfs by the then proposed 20 reservoir system and then increasing the modified flow to 248,000 cfs to allow for the estimated effects of the dikes on floodflows. The 1937 design flood was produced by approximately 7.2 inches of runoff from the basin and was estimated, at that time, to be about a 1,000-year frequency event.

TABLE 5

EFFECT OF EXISTING RESERVOIRS ON FLOODS OF RECORD

Event	Observed Discharge** (cfs)	Observed Elevation (ft msl)	Modified by 16 Existing Reservoirs* Discharge (cfs)	Modified by 16 Existing Reservoirs* Elevation (ft msl)
Mar 1936	267,500	37.0	206,100	32.4
Sep 1938	239,000	34.0	194,500	31.3

* Existing reservoirs include Union Village, North Hartland, North Springfield, Ball Mountain, Townshend, Surry Mountain, Otter Brook, Birch Hill, Tully, Barre Falls, Conant Brook, Knightville, Littleville, Sucker Brook, Mad River, Colebrook.

**Discharges at USGS gage at Middletown, Connecticut. Elevations at Memorial Bridge, East Hartford, Connecticut.

Following the record rain storm experienced in September 1938 in New England, a new design flood was developed for the Connecticut basin and reported in 1944 (reference 5). This revised design flood was developed by orientating the 1938 storm over the basin to produce maximum uncontrolled runoff, assuming high antecedent moisture conditions. This resulted in a new design natural and modified flow at Hartford of 420,000 and 279,000 cfs, respectively. This modified flow would be equivalent to a flow of about 267,000 cfs at Middletown and a stage of about 37 feet msl at Memorial Bridge in East Hartford. The revised design flood was reported in 1944; however, the East Hartford project was partially completed and was not modified.

Due to the indefinite schedule of reservoir construction at the time the East Hartford project was constructed, the earth dikes were built to provide five feet of freeboard above the original design flood level. Concrete walls were built with three feet of freeboard.

Standard Project Flood - A standard project flood (SPF) was developed for the lower Connecticut River basin in 1970 in conjunction with the Connecticut River Basin Comprehensive Study (reference 3). Its primary purpose was to test the lower basin flood potential with the existing system of reservoirs in operation. The standard project storm was therefore oriented to produce maximum runoff from the uncontrolled drainage area in the lower central portion of the Connecticut River basin. The storm was assumed to occur with relatively high antecedent moisture conditions, producing a base flow in the river of about 8 cfs per square mile.

The resulting standard project flood had a natural and modified peak flow at Middletown of 383,000 and 321,000 cfs, respectively. The accompanying modified flood stage at East Hartford Memorial Bridge would be 41.2 feet msl.

Design flood comparisons relative to flood levels at East Hartford are presented in table 6.

TABLE 6

Flood	East Hartford Flood Elevation (Memorial Bridge)	Middletown Discharge (cfs)	Hartford Discharge (cfs)
1937 Design Flood*	35 ft msl	242,000	248,000
1944 Revised Design Flood*	37 ft msl	267,000	279,000
1970 Standard Project Flood**	41.2 ft msl	321,000	---

* Modified by the then proposed 20 reservoir system

** Modified by existing 16 reservoir system

EXISTING LOCAL PROTECTION PROJECT

Height of Protection - As previously discussed, the existing project was designed, with freeboard, to protect against a flood having a level of 35.0 feet above mean sea level at the East Hartford Memorial Bridge. Heights of protection, at selected stations, are also listed in table 7.

Stage Discharge Rating - A curve relating the discharge of the Connecticut River at Middletown with flood levels at the Memorial Bridge in East Hartford is shown on plate 3A. This curve was developed from historical stage-discharge relations. The level of the SPF relative to the existing design level is also indicated on plate 3A.

Freeboard - Freeboard is the vertical distance measured from the design water surface to the top of a dike or wall. Freeboard is provided to allow for uncertainties in hydraulic computations, and to ensure that the desired degree of protection will not be reduced by unaccounted factors.

A uniform freeboard of three feet for both concrete walls and earth dike was originally proposed for the East Hartford Local Protection

Project. However, since the entire reservoir plan might not be effective for some time, the Board of Engineers for Rivers and Harbors recommended the earth section be raised two feet; therefore, the originally adopted design freeboard was five feet for earth dikes and three feet for the concrete walls. Present freeboard practice allows for three feet of freeboard for earth dikes and two feet for concrete walls. Less freeboard is provided for concrete walls due to their greater resistance to failure if overtopping were to occur.

FORMULATION OF ALTERNATIVE PLANS

As discussed in the section "Problems and Needs" there is a need for added flood protection over that which is currently provided by the existing dike system. This section will describe and analyze the various alternative measures which could be implemented to increase the flood protection in East Hartford. Plans were formulated to improve the quality of life within the study area through contributions to the objectives of National Economic Development (NED) and Environmental Quality (EQ) and meeting the desires of the public.

FORMULATION AND EVALUATION CRITERIA

Plans, in the context of the two objectives (NED) and (EQ) were prepared and evaluated on the basis of appropriate technical engineering. Each plan was evaluated for its costs and its effect on economic development, the quality of the environment, and the social impacts, in accordance with the Principles and Standards for Water Resources and Related Resources. Beneficial and adverse effects of the alternative plans are outlined and compared. Wherever possible, the options were modified to reduce adverse effects. Local participants commented on the plans and indicated their preferences.

"WITHOUT PROJECT" PROJECTION

The primary consequences of doing nothing would be that if a flood exceeding the existing protection were to occur, there would be a massive loss of property and human lives. These losses will be borne by the local residents, Federal, State and local governments for flood fighting and damage repair.

POSSIBLE SOLUTIONS

Posssible alternative measures to increase the flood protection for East Hartford fall into two broad categories; non-structural and structural. The alternative of doing nothing to increase the flood protection is discussed in the section titled "Without Project" Projection.

Non-Structural Measures - Non-structural measures do not attempt to reduce or eliminate flooding, but rather attempt to regulate the use and development of the flood plain, thus lessening the damaging effects of large floods.

Non-structural measures are currently being investigated for those areas of East Hartford which are not now protected from flooding. Refer to the "Studies in Progress" section for a summary description of the study.

Within the existing protection works there are several non-structural measures which could be implemented; relocation, flood proofing, flood warning and evacuation, flood insurance, and flood plain regulation.

Relocation - This measure would involve the permanent relocation of people and structures from the floodplain to sites outside the floodplain. Structures would be purchased and torn down, or moved from the floodplain. Floodplain occupants would be given financial and technical assistance to make their move as easy as possible.

Using relocation to achieve damage reductions comparable to the upstream storage reservoir or dike modification alternatives would require moving much of East Hartford. Although relocation does not offer a practical response for an immediate solution to damage reduction, long term consideration could be valuable. If parts of the floodplain were to undergo redevelopment or increased development, it would seem reasonable to relocate these activities outside of the floodplain.

Floodproofing - Floodproofing would consist of modifications to structures, their sites, and building contents to keep water out or reduce the effects of water entry. Buildings could be floodproofed by raising foundations above the floodplain, fitting watertight doors, or installing special window shields.

The floodplain zoning ordinance, adopted by East Hartford in 1972, requires that buildings and improvements be designed to withstand structural damage and erosion up to an elevation at least two feet above the elevation of the floodplain at 30 feet msl along the Connecticut River. Under this ordinance, heating, electric, and sanitary equipment must be floodproofed.

Flood warning and evacuation - The National Weather Service River Forecast Center in Bloomfield, Connecticut, provides formal river forecasts and flash flood guidance to New England. An effective flood warning system would provide residents some time to prepare for an impending flood by temporarily evacuating their home and removing damageable property.

Flood Insurance - The National Flood Insurance Program provides for flood coverage for all types of buildings and their contents. Under this program, local governments are required to adopt and enforce land use control measures that will guide development in flood prone areas in order to avoid or reduce future flood damage.

East Hartford is currently enrolled in the emergency phase of the insurance program. Under this phase of the program the Federal Insurance Administration (FIA) prepares a flood hazard map for the community and the community establishes minimum regulatory standards.

Before being accepted into the regular phase, detailed hydrologic, geologic, and topographic data will be collected. The FIA then will have sufficient information to establish acturial insurance premium rates. This data will also provide the community with the information it needs to establish equitable and responsible flood plain regulations. The flood insurance program does have some value to individuals who volunteer to participate. Although the Flood Insurance Act is keyed to the 100 year flood plain, insurance is available at greatly reduced rates for those areas outside of the 100 year flood plain. Since the existing dikes provide protection from floods well above the 100 year level, property owners could obtain flood insurance at reduced rates. The zoning restrictions which are a part of the flood insurance program are also limited to the 100 year event and would have no effect within the protected area.

Regulation - Floodplain regulation is a non-structural measure which can modify the future susceptibility to damage on floodplains not fully developed. Regulatory measures include encroachment laws, wetlands protection laws, local floodplain zoning, subdivision regulations, and building codes. Most of these measures are subject to state and local enactment with the exception of regulation under the Federal Flood Insurance program discussed above. Regulatory measures can be beneficial in prohibiting and discouraging new construction in high risk areas and encouraging activities compatible to floodplain management. East Hartford has established a procedure for approval of new development in the floodplain as contained in its zoning regulations. Under these regulations, approval may be granted by the Town Planning and Zoning Commission, based on comprehensive information provided by the developer. In the case of development within State established encroachment lines approval must also be given by the Connecticut Department of Environmental Protection.

Due to the highly urbanized nature of the protected area none of these measures would be efficient when compared to the structural measures. The protected area is protected from flooding up to approximately the 400 year event. If this event is exceeded and the dikes are over-topped, flood proofing, flood insurance or regulation would provide only negligible relief to the massive damage and threat to life that could occur. Relocation would solve the problem of property damage and threat to life but would cause significant social and economic impact. The effectiveness of the existing dike would be lost with nothing left for it to protect. Flood warning and evacuation of the area behind the existing dikes would be a reasonable alternative for protection to life but would be ineffective in preventing property and public facility damages.

Structural Measures - Two structural measures could provide the desired level flood protection for East Hartford:

- Upstream storage provided by construction of reservoirs and modifying the existing dike. Upstream storage provided by construction of reservoirs was investigated in previous studies of the Connecticut River Basin. Construction of reservoirs appeared to be the best plan to achieve the desired level of protection, however, the upstream states have withdrawn their support for such a plan. In support of the states' decision the Corps of Engineers deauthorized the reservoir projects in August 1977.

Modify the Existing Dike - Modification of the existing dike to provide the specified degree of flood protection would require an increase in dike elevation of 4.2 feet and the construction of extensions of the modified dike on either end to meet high ground at the new higher elevation.

The methods of increasing the height of the existing dike and of extending the dike to high ground will be presented, followed by three specific alternative plans which utilize these methods or combinations of them.

Methods of Increasing Dike Height - Two methods of increasing the height of the existing dike by 4.2 feet were investigated: earth fill or by construction of a concrete wall on the crest of the existing dike.

The earth fill would be used to increase the height by selective placement of fill such that the side slope fill would be either on the riverside or the landside of the existing dike as shown on plate 4. Landside placement of fill would be less expensive than riverside placement except where existing structures would have to be removed or where massive concrete retaining walls would be erected where the fill encroaches property. Reprap would be required on the riverside slope for erosion protection. The removal and replacement of the existing riprap where the riverside fill is used would add a significant cost. A negative impact of the earth fill method would be the temporary loss of vegetation (trees, shrubs and grasses) for a distance of approximately 25 feet from the existing toe of the dike.

The other method of modifying the existing dike would use a concrete wall. This method increases the dike elevation by constructing a 4.2 foot high reinforced concrete wall on top of the existing dike. The L-shaped wall would be positioned such that the stem would rise vertically from the riverside edge of the dike crest. Stop-log structures would be provided at openings in the wall where access ramps cross over the top of the dike. An advantage of this method is that the base of the existing dike is not widened and disruption to adjacent vegetation and wildlife habitat would be negligible. One cost advantage of this method over the earth fill method is that existing riprap would not have to be removed and replaced during construction. The concrete wall method was denounced in certain sections and locations by the general public and by the local officials. The public expressed the opinion that the wall would become the target of vandalism, graffiti, would restrict views and be too visually apparent where it was near residential areas.

Since the dike would be raised 4.2 feet, the ends must be extended beyond the existing ends in order to tie into high ground at the new higher elevation. There are several methods of constructing the extensions: earth fill, concrete wall, or temporary measures such as wooden, concrete or sandbag walls which would be erected prior to predicted high water events. The temporary measures were rejected by town officials who would ultimately be responsible for placement. The extension designs are presented separately since their design may be treated independently of that for the main dike. At the north end the extension would follow existing residential property lines. The concrete wall and sandbag extension were analyzed to reduce the impact on the adjoining properties. The trees and shrubs which would be removed during construction of the concrete wall would be replaced by the Corps. A longer earthfill

extension which would provide additional protection for over sixty homes in the Floradale and Mohawk Drive area was studied. Residents of the area voiced strong opposition at the May 1978 meeting. This alternative dike extension was rejected from further consideration due to its economic infeasibility and lack of public support.[1] At the southern end of the project an earth fill dike and a concrete wall

[1]The annual cost of extending the dike to protect the Mohawk Drive area is estimated to be $160,400. The annual benefit is estimated to be $6,000. The benefit to cost ratio for this option is .04 to 1.0.

could be used to extend the dike to high ground. The earth fill extension would begin at Brewer Lane and continue across the meadows of the Hockunum River to the corner of Central Ave and Elm Street. From the corner of Central Avenue and Elm Street a concrete I-wall would be used for approximately 1000 feet until it would meet high ground.

Grass would be planted on the landside of the dike to minimize the visual impact of the extension. The other component of this extension, the concrete wall, will have minimal impact to the area since it would be only two feet high along the residential property lines. Another earth fill dike extension plan was proposed for the southern end. This extension would start at Brewers Lane cross the meadows of the Hockanum River for about 2600 feet and meet high ground at the Town garage yard at Ambrose Terrace. This plan was dropped from further study due to high cost, the impact on the Hockanum River flood plain, adverse impact on the aesthetics of the area and the loss of plant and wildlife habitat. City officials have objected to this layout.

Plan 1 - This plan as shown on plate 5 would retain the existing dike at the same aesthetic level as the present condition within the project area. The existing dike system would be raised 4.2 feet by earth fill either on the landside or riverside as described in the preceding paragraphs. The north end extension, (Greene Terrace and Floradale Drive area), would consist of a concrete I-wall to be constructed between two private properties. Although this plan received opposition from the property owners because of the decrease in the aesthetic appeal of the property, it is felt that it is the best extension plan. The south end dike extension would consist of an earth fill dike starting at the end of the existing dike at Brewers' Lane continuing along the Hockanum River meadows to the corner of Central Avenue and Elm Street. At this point a concrete wall would be constructed along Elm Street for approximately 1000 feet where it would meet high ground. Included in this plan would be modifications to the existing structures such as the I-wall, concrete buttress wall, and two stop-log structures. For further details of these structural modifications refer to plate 4.

Plan 2 - This plan as shown on plate 6 was developed to minimize disruption to the existing dike system, to keep the land acquisition to a minimum and to reduce construction cost and still meet the planning objective.

The existing dike will be raised 4.2 feet by constructing a reinforced concrete L-wall on top of the existing dike. The concrete stem will be placed on the crest of the dike on the riverside. Stop-log structures would be required at openings in the concrete wall where maintenance ramps cross over the top of the dike. For further details refer to plate 4. The north end dike extension, south end dike extension and the modifications to the existing structures would be the same as in Plan 1. This plan was unacceptable to the residents abutting the dike and to the town officials because they felt that the concrete wall would become the target of vandalism, graffiti and that the visual appearance would be offensive.

Plan 3 - This plan as shown on plate 7 was formulated after the public meeting on 31 May 1978, in response to opposition to Plan 1 and 2 from the mayor and local residents. Plan 3 would consist of a combination of the first two plans; the earth fill method would be specified in the residential and the downtown areas near the Founder's Place for aesthetic reasons. The concrete L-wall method would be used for the remaining areas. The north and south end extensions would be as indicated in Plan 1. Modification to existing structures would be made as indicated for Plan 1.

EFFECTS ON OBJECTIVES

The Water Resource Council's Principles and Standards require that alternative plans continually be evaluated against planning objectives of national economic development, environmental quality, regional development, and social well-being. Interacting social, economic, and environmental factors may bring about both adverse and beneficial impacts which may have short or long term effects.

Section 122 of the River and Harbor and Flood Control Act of 1970 specifies certain elements that must be considered in the effects assessment to assure that possible adverse economic, social and environmental effects relating to the proposed project have been considered. Those adverse effects include air, noise, and water pollution; destruction or disruption of man-made and natural resources, aesthetic values, community, cohesion, and the availability of public facilities and services; adverse employment effects and tax and property value losses; injurious displacement of people, businesses, and farms; and disruption of desirable community and regional growth. These effects are not inclusive of all those that may be discussed in an assessment.

Impacts of varying magnitude and longevity can be expected to occur during the two phases of the project; the construction and the post-construction phase. Impacts likely to occur during the construction phase are generally short-term in their effect on the study area. The post-construction phase is characterized by long-term impacts that are expected to extend over the life of the project.

Construction impacts are short-term and will be similar for all options. Effects related to construction activities include increased temporary employment, increased traffic on local roads, increased air and noise pollution, hindrance of land use on or near the dike location.

The construction phase will last for a period of 2 years. Approximately 90 workers will be required to carry out construction. It can generally be anticipated that 75% of these will be hired in the local area. The other 25% will consist of a skeleton crew supplied by the contractor.

The effect of increased traffic will depend on the source and quantity of construction material required, the access to dike location, and general quality of road surfaces. The extent of these effects is unknown at this stage of the study. However, it is expected that access to dike locations will necessitate travel through residential areas, increasing safety hazard for neighborhood residents, as well as air and noise pollution levels. Although, the effect on industrial roads, which are used to managing heavy truck traffic, may not be as great, the increased trucking could slow down normal operations.

Temporary easements on private property, totalling about 12 acres, will be taken for approximately two years to store construction materials and equipment during actual construction.

The major long-term impact resulting after construction of the project would be additional flood control protection. As detailed in the economic benefit analysis section, the potential destruction that would be realized in the event of a standard project flood would be immense. Damages would exceed 121 million dollars and would affect 220 commercial structures, 42 industrial structures, 34 public structures including the Metropolitan District Commission's (MDC) Water Pollution Control Plant, and 396 residential structures.

While there would likely be a significant warning time for a major flood on the Connecticut River there would be no certainty regarding the probability and timing of a potential dike failure. Therefore, in addition to the extensive disruption of economic and social activities due to overtopping of the dike and the threat to the health of the populace, there exists a sizeable potential threat to the lives of people residing and working behind the dike.

Impacts Specific to Raising The Existing Dike - Impacts specific to raising the existing dike will vary only slightly with each plan. The variations among these plans are differences in the land taking and general aesthetics.

Plan 1 - Impacts - This alternative will utilize earth fill to raise the existing dike. Current land use and physical structures abutting the dike would dictate whether the additional earth fill will be placed on the landside, riverside, or some of both. In most cases where there is currently riprap on the riverside, the fill will be placed on the landside due to the high costs of removal and replacement of the riprap. A negative impact of fill placement would be the destruction of vegetation (trees, shrubs and grasses) for a total of approximately 25 feet from the existing toe of the dike. Lands required in permanent easements totaling approximately 30 acres would be required. No removal of homes or structures would be required in the area. This fill would also destroy some terrestrial habitat currently utilized by small mammals and birds.

Although this plan is the most visually appealing there will be a negative impact of the dike raising in certain areas where visibility will be restricted due to the increased height. This will be most prominent in the residential areas at either end of the dike system. Some residents may feel more "closed in" with increased dike height.

In an effort to lessen the impact, the dike would be grassed which will not be as visually obtrusive to the area as if it were riprapped.

It is not envisioned that this alternative would impact any sites of archaeological significance, since the area was greatly disturbed during initial construction, and the area's terrain is steep and wet in places. Coordination with the State Historic Preservation Officer will be maintained during all stages of the project.

Implementation of this alternative would not preclude the dike system from being used for passive types of recreation such as a bikeway or walking path. Further coordination with the Recreation Commission would determine whether or not such a plan would be feasible.

Plan 2 - Impacts - This alternative consists of constructing a 4.2 foot concrete wall directly on the crest of the existing dike. An advantage to this technique is that the base of the dike does not have to be widened by 25 feet, and consequently there will be no disruption to adjacent vegetation and wildlife habitat. Also, this alternative would not require riprap to be removed and replaced.

There has been expressed concern from the residential areas about the visual appearance of this concrete wall alternative. The plan would also restrict current views and would be more visually apparent winding through a residential area. Even though the concrete can be textured to increase its aesthetic appeal, some adjacent landowners are worried that it would become the target of vandalism and graffiti.

This alternative would not lend itself as well as Plan 1 for implementation of passive recreation since the wall would run along the riverside edge of the dike crest.

<u>Plan 3 - Impacts</u> - This plan would essentially be a combination of Plans 1 and 2, and would favor components which strike a balance between environmental impact and project cost. By utilizing the different techniques to raise the dike, impacts to the physical and social environment can be kept to a minimum.

Impacts Specific to Dike Extensions - Since the dike, for each of the alternatives, will be raised 4.2 feet, the ends must be extended to meet high ground. For the northern end, the extension can be accomplished by a concrete wall or sandbags. Impacts with the wall will be more apparent since it would extend into or along residential property. Some trees and shrubs would have to be removed during construction, but would be replaced with new plantings according to a new landscape development plan. The alternative of sandbagging to high ground is also being considered. This would not impact as much in a physical sense but would not be as foolproof as something permanent. Less than one acre of land would be required for this extension.

In order to tie into ground at the southern end of the project a new dike and concrete wall system is proposed. The dike would extend from Brewer Lane to the corner of Central Avenue and Elm Street. It would pass through a low meadow adjacent to the Hockanum River and would require about 7.7 acres to construct. Wildlife presently using this area would be displaced or destroyed, although this impact is forecast as minor according to the U.S. Fish & Wildlife Service. The aesthetics of this area will be lessened by the loss of plants and by the placement of the dike into the area. The landside of the dike will be grassed to help cut down on the visual intrusion of it to the surrounding area. Once again, landscaping will accompany the dike in appropriate areas. The other component of this extension will be a concrete wall which will continue from the end of the dike and run along Elm Street to nigh ground. The visual impact of this wall will be neglible since it will only be about two feet high.

Impacts on Land Use Development - Because of the current level of flood protection offered, dike raising will have limited impact on land use development. It is possible that the dike raising will have a negative effect by restraining development, instead of encouraging development with the increased protection. This restraint would be felt in scattered locations along the existing dike. By raising the dike on the landside the width of the base would be increased 25 feet. This could infringe upon development, perhaps in Founders Plaza, where some preliminary plans for new office space have already been formulated. However, final plans could be revised to provide for riverside raising in choice locations.

Concerns of Local Residents - The concern of local residents on the flood issue as reflected in the May 1978 public meeting are based mostly on aesthetics; removing the remaining view and disturbing existing wildlife. Many residents indicated an awareness of the flood rise, but felt that it was not severe enough to increase their protection by removing or eliminating those things that had initially attracted them to their current location. As well as limiting the existing view, some residents were concerned with the likelihood of graffitti appearing on any concrete walls constructed as part of the project, further detracting from local aesthetics.

SUMMARY OF ALTERNATIVES

Nonstructural and structural alternative solutions were investigated to solve the flood control problem in East Hartford. Nonstructural alternatives would not be effective in providing the desired level of flood protection within the area protected by the existing dike. The two structural solutions; upstream reservoir storage and modification of the existing dike were investigated. Upstream storage reservoirs would not be acceptable to upstream communities in the Connecticut River Basin. Therefore, modifications to the existing dike was the only remaining alternative which would meet the objectives of the study. Three alternative plans for modifying the existing dike were investigated. All plans would increase the existing dike elevation by 4.2 feet to provide for SPF protection. Plan 1 would use earthfill for raising the dike. Plan 2 would use a concrete wall on the crest of the existing dike. Plan 3 would be a combination of the Plans 1 and 2 methods of raising the dike to minimize the social and environment impacts of the dike modification. Economic analysis of the three plans indicated that Plan 1 would be the most costly and that Plan 2 the least costly. Since the benefits provided by the modification would be equal for all plans, Plan 2 would be the most feasible and could be considered the National Economic Development (NED) plan. A summary of the economics of the alternatives are shown on Table 8.

TABLE 8

SUMMARY COMPARISON OF ALTERNATIVE PLANS

	Alternative 1 Do Nothing	Alternative 2 Flood Plain Management	Alternative 3 Modification of the Existing Dikes		
			Plan 1	Plan 2	Plan 3
Plan Data					
Implementation Cost:					
Federal Cost	-	-	$8,677,000	$4,046,000	$4,205,000
Non-Federal Cost	-	-	317,000	179,000	245,000
Total Cost	0	0	$8,994,000	$4,225,000	$4,450,000
Average Annual Flood Damage (Benefits) w/o Dike	$5,213,000	$5,213,000	$5,213,000	$5,213,000	$5,213,000
Average Annual Flood Damage (Benefits) w Dike	$ 171,000	$ 171,000	$ 171,000	$ 171,000	$ 171,000
Average Annual Charges	0	0	$ 618,400	$ 290,500	$ 306,000
Benefit - Cost Ratio w/o Dike	0	0	8.4 to 1.0	17.9 to 1.0	17.0 to 1.0
Benefit - Cost Ratio w Dike	0	0	0.21 to 1.0	0.59 to 1.0	0.56 to 1.0

Life of project used in economic evaluation of the project 100 year

Interest Rate 6-7/8

Plan 3 is the most receptive plan from the environmental and social viewpoints since it would cause the least disruption to the physical and social environment. Since Plan 3 has the minimal environmental impact it could be considered as the Environmental Quality (EQ) Plan.

ECONOMIC ANALYSIS

GENERAL CRITERIA

The economic analysis of the East Hartford project presents a different set of circumstances from the typical benefit to cost analysis. This difference arises due to two factors: (1) the proposed project is a modification of an existing structure, and (2) the original system, for reasons mentioned below, has not been completed.

U.S. Army Corps of Engineers guidelines as outlined in Department of the Army Engineering Regulation (ER) 1105-2-200 specifies the following (page 16):

"There are two basic criteria for plan recommendation: the net benefits rule and Corps authority to implement .....

Net Benefit Rule - A recommended plan when considered individually on the basis of "with vs. "without" comparison must be justified in the sense of total beneficial contributions (monetary and nonmonetary) exceed total adverse contributions (monetary and nonmonetary). Further the recommended plan must have net NED benefits unless the deficiency is the result of NED benefits foregone or costs incurred to obtain positive EQ (non-monetary) contributions. This means that a recommended plan which has no net economic benefits must make positive contributions to the environment when evaluated against the without condition. Exceptions to the net benefit rule will be extremely rare and will be based upon prior approval by the Secretary of the Army; ... Exceptions might include unique and overriding social considerations, such as extreme loss of life..."

The "with" vs "without" comparison mentioned above is defined in Department of the Army Engineering Pamphlet (EP) 1165-2-1 as follows:

"With and Without Consequences - The with and without consequences of each feasible alternative should be determined adequately. The net effect of any proposed solution to a water resource problem should be carefully considered under a with and without action framework, using projections of economic, environmental and social impact indicators. Beneficial and adverse project impacts are evaluated by measuring the differences between indicator values which result if a proposed plan is implemented and their values if the natural forces of change continue to develop free of the influence of a development action by the Corps or any other Government action."

One further piece of information is required to complete the puzzle. Department of the Army, Draft Engineering Circular (EC) 1105-2-86, dated 16 June 1978 discusses the level of protection that is to be designed for urban flood control.

"'Policy on Level of Protection'- On the assumption that an exceedance of the design flow would cause a catastrophe, the Standard Project Flood (SPF) is the minimum level of protection that District Engineers should recommend for high levees, high floodwalls, and for high velocity channels in urban areas."

"'Catastrophe' is an event causing sudden and widespread misfortune, distruction or irreplaceable loss; a catastrophe may be said to occur when many human lives are endangered, human lives may be or have been lost, or when extensive property damage occurs, either in small urban communities or large metropolitan areas."

"'Standard Project Flood (SPF)' is a hypothetical flood that might be expected from the most severe combination of meteorological and hydrological conditions that are considered reasonable characteristic of the geographical region involved, excluding extraordinarily rare combinations. This definition is taken from Department of the Army Engineering Manual (EM) 1110-2-1411, which provides specific instructions for computing the standard project flood."

The original system of dikes and reservoirs as designed, would have provided protection to East Hartford and six other cities along the mainstem of the Connecticut River in the event of an occurrence of the standard project flood. The Rivers' Reach, (p. 31) a report on a unified program for flood plain management in the Connecticut River Basin prepared by the New England River Basins Commission, discusses why six of the above cities including East Hartford have not been provided standard project flood protection.

"The Corps of Engineers explains how it came about that the system which it designed and built achieves standard project flood protection in Hartford but not in the other six cities:

"'The 1938 Flood Control Act authorized a plan of flood damage reduction. The plan recommended seven local protection projects on the Connecticut River mainstem to provide protection from a recurrence of a 1936 magnitude flood and the construction of a system of large reservoirs on upstream tributaries, so that a design flood similar to today's standard project flood could be reduced to a point where the dikes would not be overtopped.

"Hartford contributed an additional $5 million to have its protective works constructed to the design flood level without considering the construction of upstream reservoirs. Today, Hartford is considered safe from a standard project flood.

"Sixteen tributary reservoirs have been constructed. Sixteen reduce flood stages at Hartford and East Hartford. Thirteen reduce stages at Springfield and West Springfield, eleven reduce stages at Chicopee, and nine reduce stages at Holyoke and Northampton. However, the level of tributary control envisioned in the 1930's has never been realized. The Corps, up to 1970, had urged that the system be completed with the construction of seven new reservoirs and a plan of complimentary nonstructural measures. The Corps has been unsuccessful in building these new reservoirs because the states involved withdrew their support after 1970.

"East Hartford, Springfield, West Springfield, Chicopee, Holyoke, and Northampton do not now have the level of protection that was authorized by the 1938 Flood Control Act. A standard project flood would overtop all of their local protection projects, causing catastrophic losses.'"

As detailed in the benefit section the potential destruction that would be realized in the event of a standard project flood would be immense. Damages would exceed 121 million dollars and would affect 220 commercial structures, 42 industrial structures, 34 public structures including the Metropolitan District Commission's (MDC) Water Pollution Control Plant, and 396 residential structures. While there would likely be a significant warning time for a major flood on the Connecticut River there would be no certainty regarding the if and when of a dike failure. Therefore, in addition to the extensive disruption of economic and social activities due to overtopping of the dike and the threat to the health of the populace, there exists a sizeable potential threat to the lives of people residing and working behind the dike. The catastrophic potential mentioned in the regulations exists in East Hartford.

On the basis of the above discussion it was determined that the economic analysis could be performed utilizing four approaches.

1. Modified with and without analysis - Dollar benefits are computed as if the existing dike was not present. These benefits are compared against the cost of providing the SPF level of flood protection calculated via two methods: (a) the cost of providing the additional height of protection plus the cost of the original project updated to current dollars; and (b) the cost to build a dike to SPF levels if no dike existed. The benefit to cost ratios computed utilizing the costs calculated under method (a) will be a measure of the quantity of money invested in providing SPF protection to the town of East Hartford. Benefit to cost ratios computed using the costs calculated under method (b) will be a measure based, in essence, upon the Congressional intent in 1938 to provide SPF protection.

2. Strict with and without analysis - Dollar benefits are computed using the existing dikes as a base. This is an incremental analysis.

3. Alternative modified with and without analysis - Dollar benefits are computed ignoring the existing dikes. All flood control benefits are credited to the cost of raising the dike under this approach.

4. Benefit to cost ratio not relevant - The project is defective in

the sense that it does not meet the Congressional intent to provide adequate protection, as specified by Corps criteria. The following performance parameters will be used instead of traditional benefit to cost analyses to reflect changed conditions:

a. The overall project must be justified in the sense of (1b) above.

b. Strict application of the without condition in the sense that (2) will be provided but no plan will be eliminated because resultant benefits do not exceed costs.

c. The overall project must be the best means of providing the additional degree of protection, monetary and nonmonetary factors considered. (This is discussed in the Plan Formulation Section of this report).

d. The ratio of single event standard project flood (SPF) damages to first costs will be presented.

The most appropriate of the four approaches is felt to be the fourth. This will ensure that all benefits and costs will be presented to the Congress and the town. It will provide a clear and complete analysis upon which they can weigh the trade-offs and requirements and come to a decision.

BENEFIT CALCULATION

Experienced Flooding - The town of East Hartford has been subject to periodic flooding from the Connecticut River. The largest flows of recent record occurred in March 1936, September 1938, and August 1955. The flood of record, in 1936, caused $2,799,000 dollars in direct and indirect losses, inundating a large portion of the town from the river east to approximately Main Street. After the flood of 1936 and that of 1938 the existing dike was built to protect the town and it is estimated that between its completion in 1943 and 1977 this dike has prevented 7.8 million dollars of damage. (These are not 1977 dollars, but rather represent a summation of year of occurrence dollars.)

Damage Survey - During 1977 and the first half of 1978, U.S. Army Corps of Engineers personnel performed a detailed damage survey in East Hartford, in the area behind the existing dike and in the Mohawk Drive area, to determine the potential monetary impact of a flood up to three feet higher than 1936 flood crest levels.[1] This damage survey was assisted by the cooperation of local officials and

[1] Unless specially stated otherwise, the damage and benefit analysis will be based upon the area currently protected and will not include the Mohawk Drive area.

property owners and/or managers who showed highwater marks and provided experienced dollar damages. Such damages are routinely summarized by stages and structure type, i.e., commercial, industrial.

Recurring Losses - Recurring losses are those losses which would occur if the crest elevation of the 1936 flood should again be reached, and the development conditions were those of 1977. These potential losses were estimated during the field surveys by Corps damage appraisers. The following losses would be associated with such a flood height given the specified conditions:

no flood protection from dikes or reservoirs	\$90.0 million
with flood control reservoirs but no dikes	\$58.0 million
with both flood control reservoirs and dikes	\$0.0 million

Under a repeat of the 1936 flood crest without any flood protection from dikes or reservoirs, the following figures and percentages would be experienced.

TABLE 9

DAMAGES BY CATEGORY - 1936 FLOOD LEVEL

Structure Type	Damage (Millions)	Percentage of Total
Commercial	50.1	55.1
Highways	5.6	6.2
Industrial	9.8	10.8
Public	4.3	4.8
Residential	17.4	19.2
Vacant Lots	1.3	1.4
Vehicles	2.4	2.7
TOTAL	90.0	

At three feet over the crest elevation of the 1936 flood and no protection, damage figures would be experienced as shown on Table 10.

TABLE 10

DAMAGES BY CATEGORY - 1936 FLOOD LEVEL PLUS 3 FEET

Structure Type	Damage (Millions)	Percentage of Total
Commercial	60.4	50.0
Highways	5.8	4.8
Industrial	11.0	9.1
Public	6.1	5.1
Residential	33.2	27.4
Vacant Lots	1.8	1.5
Vehicles	2.6	2.2
TOTAL	121.0	

At a flood level three feet over the 1936 flood crest elevation, 220 commercial structures, 42 industrial structures, 34 public structures, and 396 residential structures would be damaged.

Annual Losses. Recurring losses summarized by stages are combined with hydrological stage-frequency data to obtain a damage-frequency relationship. This procedure is outlined on Plates 8. The damage-frequency relationship determines an annual loss figure which is utilized in the determination of annual benefits. The annual loss figure represents the average annual flood damage which will occur given the probabilities associated with floods of different magnitude, as depicted in the stage-frequency curve Plate 3.

Loss computations were made on the basis of several conditions. These conditions and their associated losses are presented in Table 11.

TABLE 11

ANNUAL LOSSES

Condition	Loss
Natural condition as modified by the reservoirs but without the existing dike	$5,262,000
Losses above the .25 percent probability event	$ 220,000
Losses above the .2 percent probability event	$ 185,000
Losses above the .1 percent probability event	$ 98,000
Losses above the .05 percent probability event	$ 49,000

No losses are calculated for the dike and appurtenant structures should they be overtopped and damaged. This is due to the damages being a function of very specific conditions associated with the flood, i.e., water velocity, speed with which the water rises. This assumption woould lead to some understatement of the potential losses.

BENEFIT ANALYSIS. There are six types of benefits which are analyzed with respect to the modification of the East Hartford protection project and they are as follows: flood inundation, future flood inundation, affluence, intensification, location, and area employment benefits.

Benefits are calculated assuming that the existing dike does not accrue benefits (Approach 3) and that the existing dike does accrue benefits (Approach 2).

a. Flood Inundation Benefits

Benefits accruing to the proposed East Hartford project modification are as follows:

1. Ground up:

(a) protection to the .25 percent probability event	$5,042,000
(b) protection from the .25 to the .2 percent probability event	$ 35,000
(c) protection from the .2 to the .1 percent probability event	$ 87,000
(d) protection from the .1 to the .05 percent probability event	$ 49,000
(e) residual losses	$ 49,000

2. Incremental: $ 170,000

Incremental protection afforded by the proposed dike raising -

this is equal to the sum of benefits 1.(b), (c), and (d).

b. Future Inundation Benefits

Future inundation benefits are based on the value of a reduced flood hazard to economic activities that would locate in the flood plain in the future. While there is planned future development within the protected area of East Hartford, there is no attempt to quantify these benefits for the present analysis.

c. Affluence Benefits

This benefit is based on the assumption that the contents of residential structures will increase in value as the incomes of the owners of the residences increases. This benefit accrues from the project's protection of increasingly valuable residential contents in the flood plain.

For the purposes of this analysis it is assumed that no affluence benefits would accrue to the project.

d. Intensification Benefits

Intensification benefits are based on the ability of activities, already located in the flood plain to utilize their land more intensively due to the reduced risk of flooding.

Based upon a discussion with the East Hartford town planner, there is no land that would be affected by the raising of the dike. While these benefits would be significant in analyzing the project from the ground up, it would be misleading to add these benefits to the flood inundation benefit since, due to the methodology employed, that benefit includes those intensification benefits which would accrue to the existing dike.

e. Location Benefits

Location benefits calculate the value of making protected floodplain land available to new activities that would use the floodplain only with the project. As discussed under intensification benefits, while this would be significant for the ground up case not for the incremental, it is already included for the former under flood inundation benefits.

f. Employment Benefits

In labor market areas which have been designated as redevelopment areas the Water Resource Council's "Principles and Standards" direct that the project benefits shall be considered to be increased by the value of the local labor required for project construction. Otherwise, it is assumed, labor would not be utilized or would be under utilized.

East Hartford qualifies as a Title IV redevelopment area under the substantial unemployment (category 8) criteria. At this stage of the study these benefits are not quantified.

In addition to the benefits accruing to the proposed modification discussed above the project would yield intangible benefits. Intangible benefits are those benefits associated with the construction of a flood control project that are not appropriately quantifiable in dollars. Flood prevention reduces or eliminates the likelihood of death or serious injury from floods. Water pollution, disease, or contamination are partly or wholly avoided. Municipal services are less strained and/or more easily able to deal with contingencies. Public morale is bolstered both during flood emergencies and in anticipation of them.

ANALYSIS

As was discussed in the assessment portion of this report benefit to cost ratios are calculated following four different approaches. The benefits used in this comparison are based upon protection being provided to the .05 percent probability event. Extrapolating the stage frequency curve the SPF flood elevation yields a frequency of less than the .05 percent probability flood. However, it was considered inappropriate to make benefit computations to the extrapolated value of the SPF due to the unreliability of the frequency curves in this range and the small amount of benefit realized when converted to an annual base. The smaller more frequent events give reasonable reliability for perhaps 20 to 50-year floods, but beyond this the reliability begins to lessen. Floods classified as 100-year and less frequent have a questionable degree of dependability and may vary considerably with the type of plotting paper, or the skew coefficient considered applicable. For example, the March 1936 record flood in the Connecticut River at Thompsonville would not even fall on a frequency curve derived from data prior to 1936. Similarly the 1955 flood in southern New England would not be on pre-1955 frequency curves for many rivers. Mainly, it was because of this questionable reliability of frequency analyses that the Corps of Engineers, for design purposes, adopted the SPF as a "standard" against which the degree of protection finally selected for a project could be judged and compared with protection provided at similar projects in other localities. The SPF has no assigned frequency - it is simply a relative measure of the flood potential of a watershed.

Combining the above discussion of the SPF with the very minute weighting which damages experienced in this frequency range receive, the use of the .05 percent probability event as an upper limit was considered appropriate.

Benefits are assumed to be the same for all alternatives since only one or two additional residential structures would be affected by the dike extension which tie to high ground, and these would experience flooding only at less frequent events.

Annual benefits used in the following benefit to cost ratios are $5,213,000 for the ground-up case and $171,000 for the incremental case.

TABLE 12

Benefit to Cost Ratios

	APPROACH 1	
	Method 1	Method 2
	Updated Cost of Existing Plus Cost of Increment [1]	Dike Built Today[2]
Plan 1	2.2	
Plan 2	2.6	
Plan 3	2.6	
Existing Dike Built to SPF Levels		3.5
	Approach 2	Approach 3
Plan 1	0.3	7.3
Plan 2	0.6	14.3
Plan 3	0.5	13.6

1. The cost utilized in this ratio is the sum of a price updated annual cost of building the existing dike ($1,854,000) and the cost of the various incremental plans as detailed in the cost section of

the report.

2. Based on cursory estimate of the cost of building the entire 20,000 feet of earth fill with riprap slope protection where required, three pumping stations and two stop-log structures.

It should be borne in mind that many losses that are defined as recurring would not exist if it weren't for the dike. Without the existing dike, flood occurrence would either deter significant numbers of businesses or individuals from locating in the floodplain or force them to make flood proofing adjustment so that recurring damages would be greatly reduced. However, significant location and intensification benefits would accrue if a dike were being constructed for the first time, although they would be less than the reduction in recurring damages.

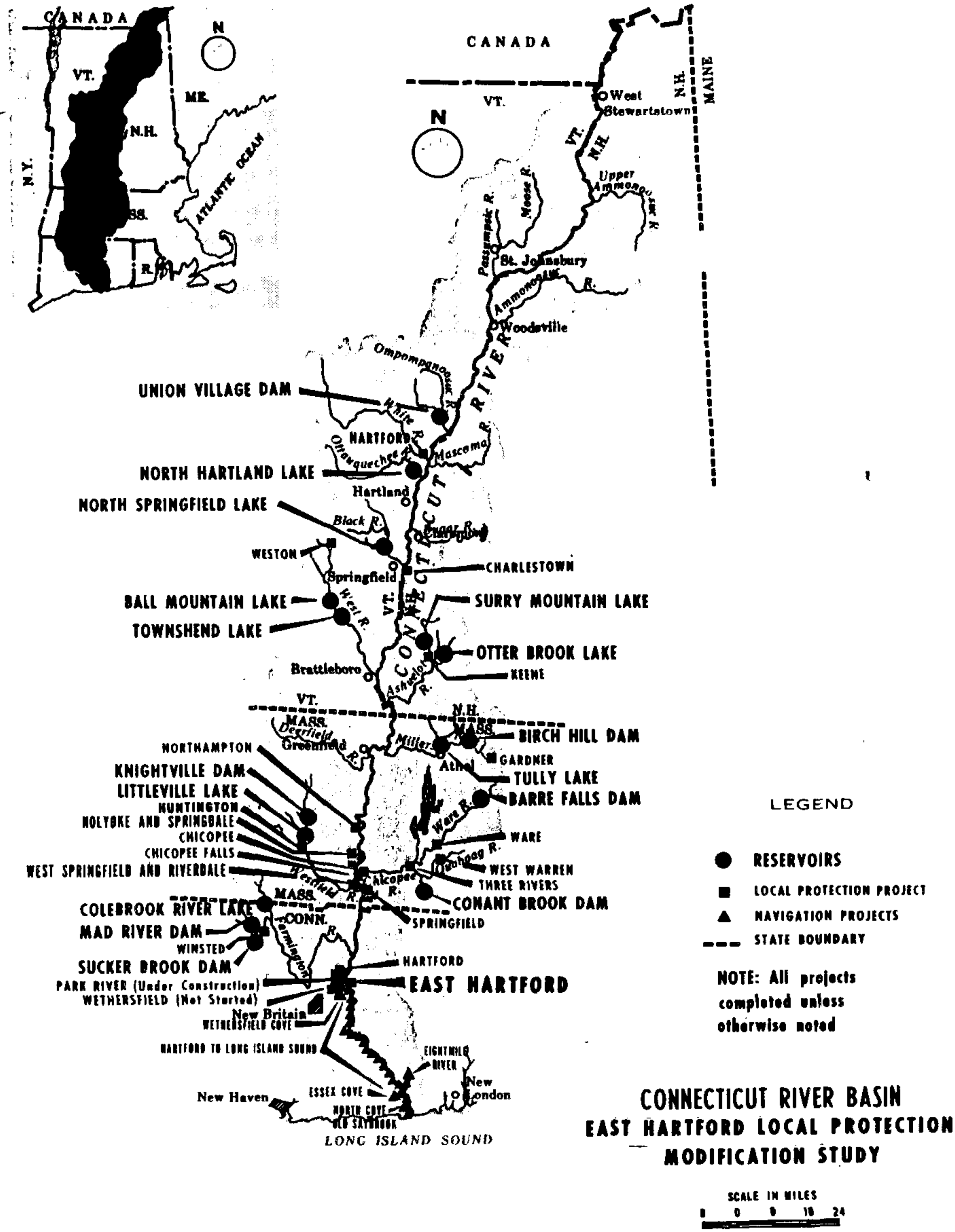
In addition to the quantified flood damages which would occur at SPF flood levels there would be sizeable non-quantifiable losses associated with economic and social disruption.

DIVISION OF PLAN RESPONSIBILITIES

Legislative and administrative policies have established the basis for federal and non-federal responsibilities in the construction, operation, and maintenance of federal water resource development projects. Non-federal responsibilities include sharing of cost for construction, and operating and maintaining the project after construction is completed. Also in areas when sand bagging is preferable over stop-log structure, the responsibility of placing sand bags in those designated areas during high intensive storms would be the responsibility of the town of East Hartford. General non-federal requirements, such as indemifying the United States from damages and preventing encroachments upon project channels will be set forth in the final report.

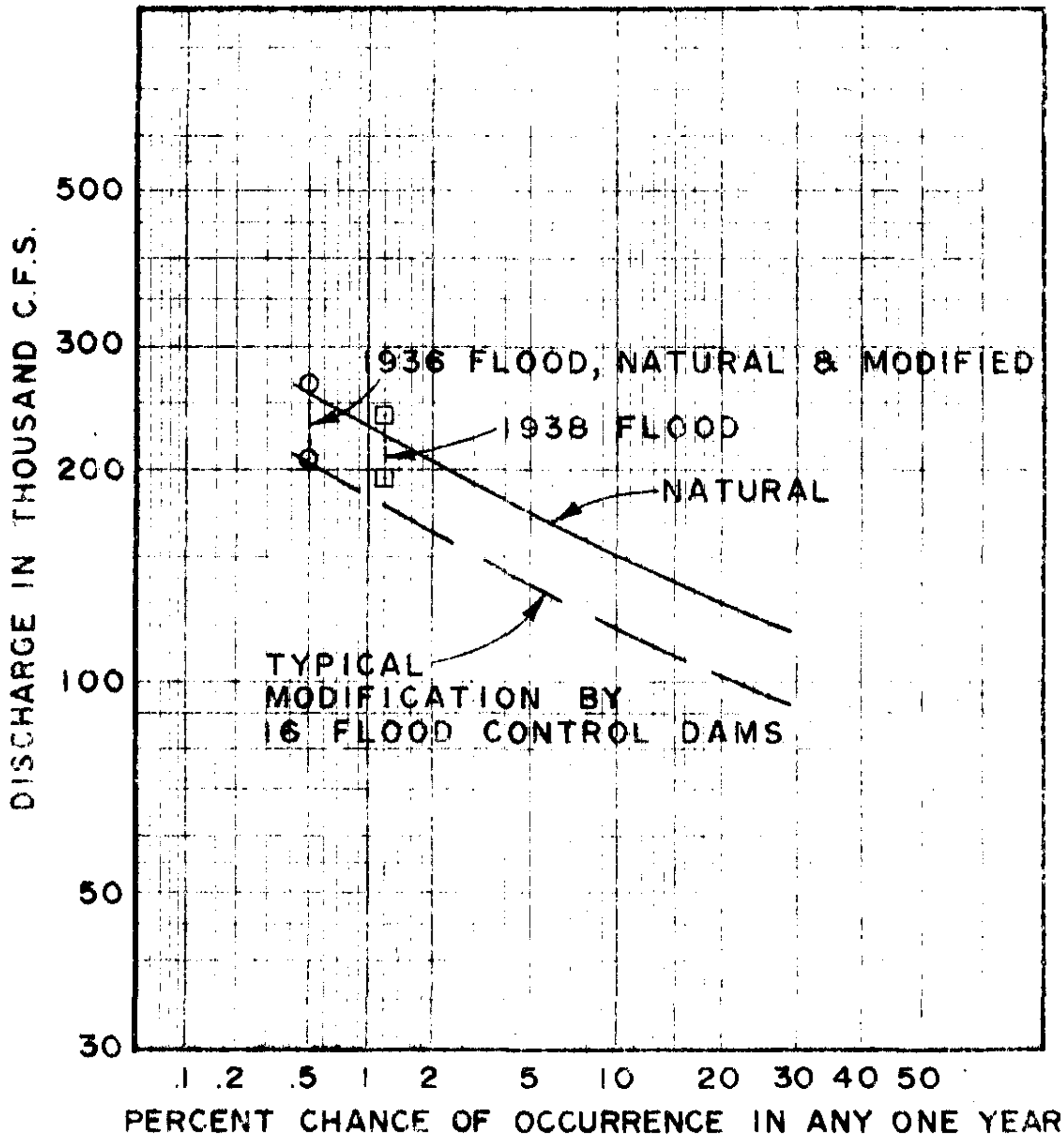
COST APPORTIONMENT

Sharing of cost between federal and non-federal interest for the modification of the existing dike system for added protection to the downtown area of East Hartford is based on the standard requirements established as federal policy for "local protection" will be required to furnish all lands and rights-of-way and compensate for damages, including relocations, required by the plan. Non-federal interests also will bear the cost of operating and maintaining the project features after construction, in accordance with federal requirements. The federal government will be responsible for all construction costs of project flood control features including project landscaping and restoration.



CONNECTICUT RIVER BASIN
EAST HARTFORD LOCAL PROTECTION
MODIFICATION STUDY

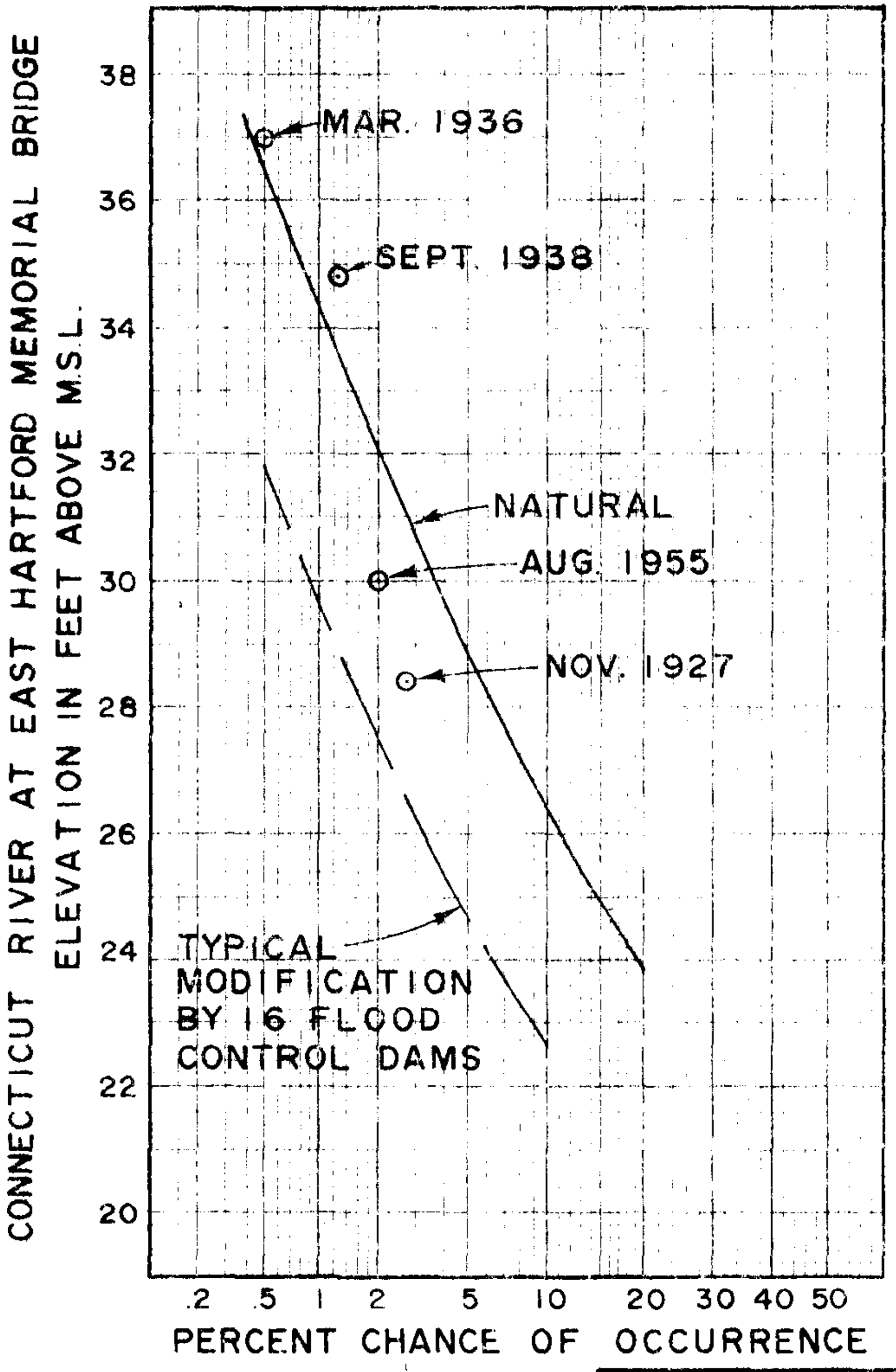
PLATE 1



CONNECTICUT RIVER

DISCHARGE FREQUENCY CURVE AT MIDDLETOWN, CONNECTICUT

PLATE 2



CONNECTICUT RIVER

ELEVATION FREQUENCY CURVE

HARTFORD MEMORIAL BRIDGE

PLATE 3

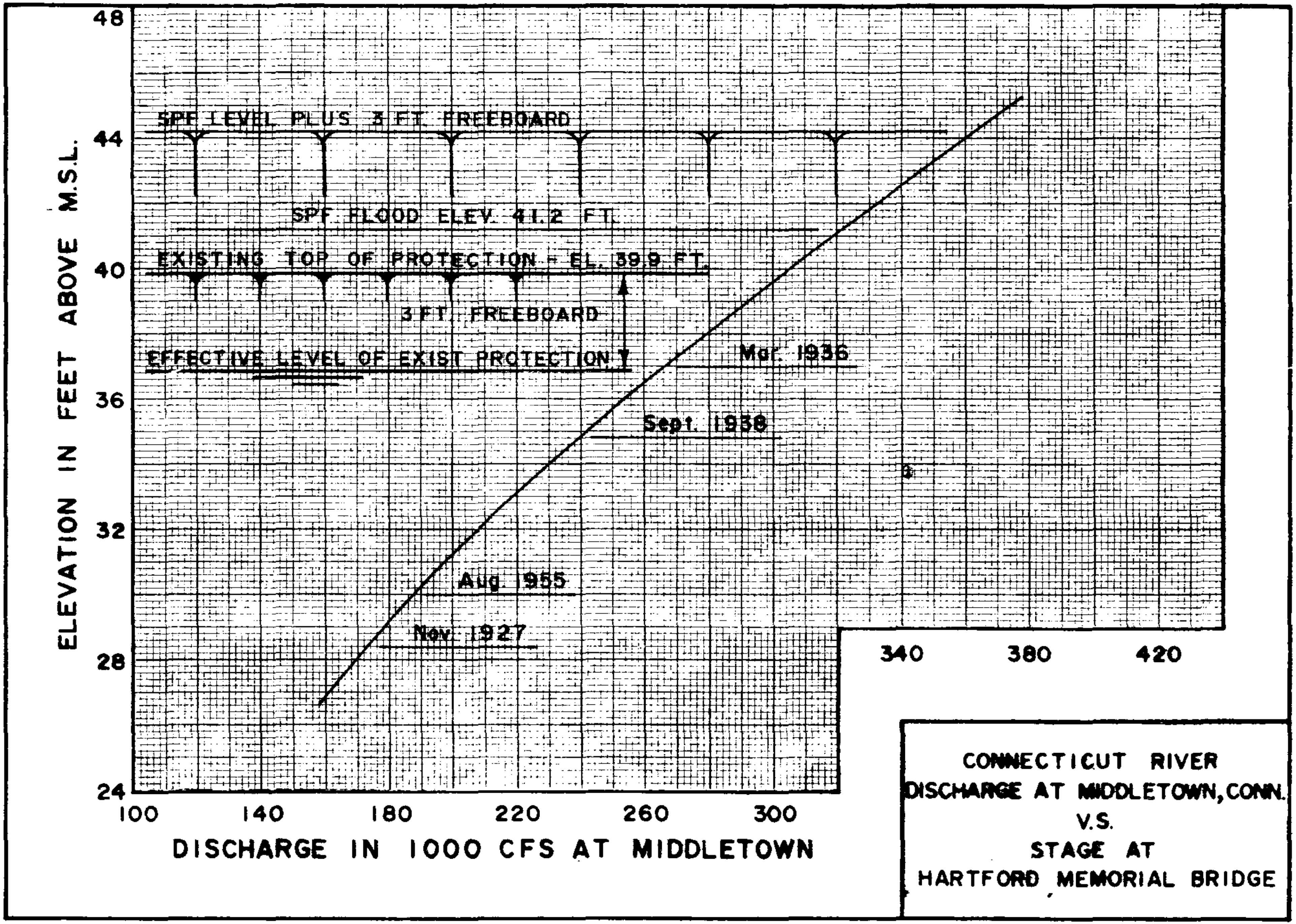
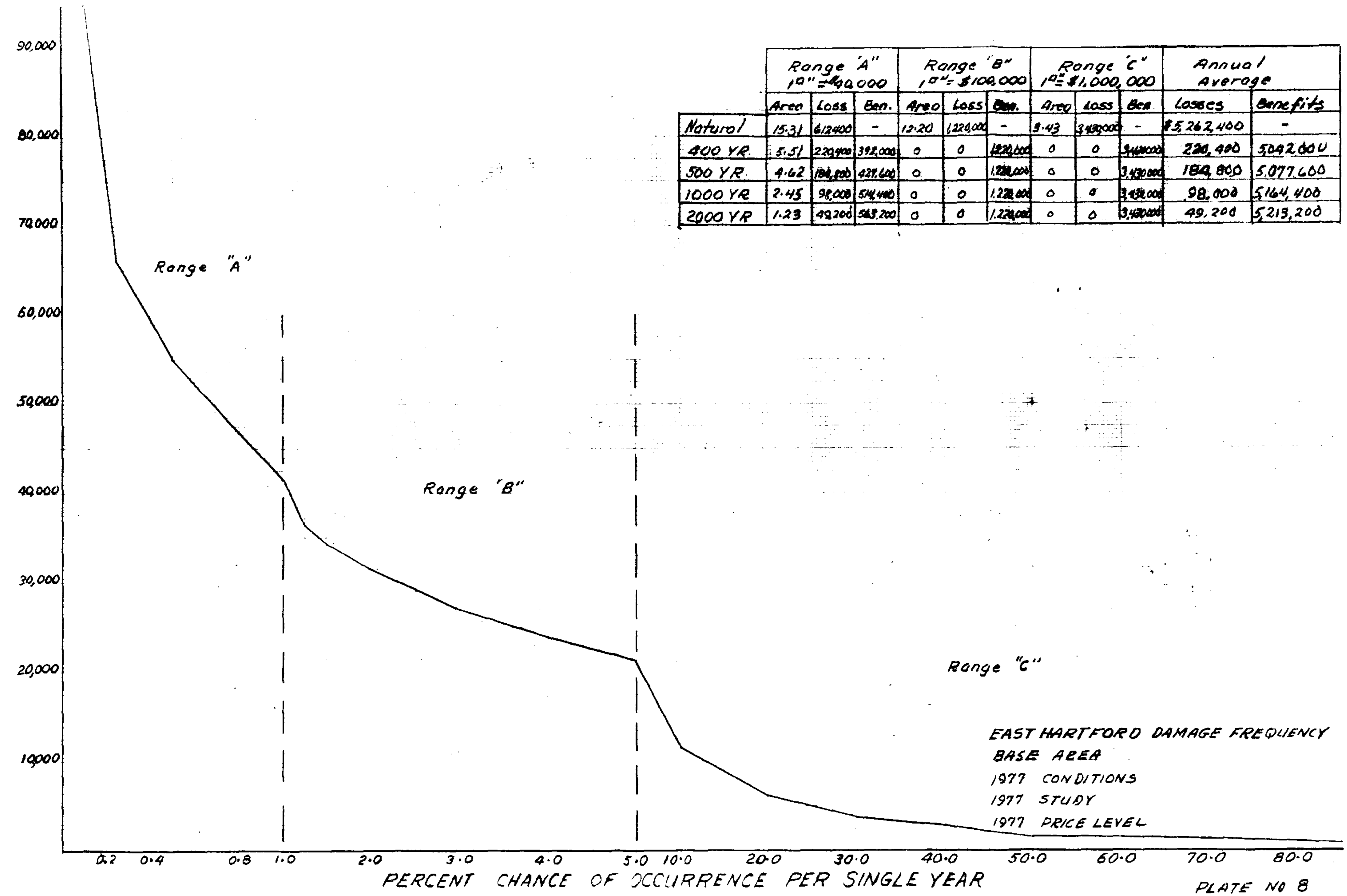

SPF LEVEL PLUS 3 FT FREEBOARD
SPF FLOOD ELEV. 41.2 FT.
EXISTING TOP OF PROTECTION - EL. 39.9 FT.
3 FT. FREEBOARD
EFFECTIVE LEVEL OF EXIST PROTECTION
Mar. 1936
Sept. 1938
Aug. 1955
Nov. 1927
48
44
40
36
32
28
24
100
140
180
220
260
300
340
380
420
ELEVATION IN FEET ABOVE M.S.L.
DISCHARGE IN 1000 CFS AT MIDDLETOWN
CONNECTICUT RIVER
DISCHARGE AT MIDDLETOWN, CONN.
V.S.
STAGE AT
HARTFORD MEMORIAL BRIDGE

PLATE 3A

	Range "A" 1" = $40,000			Range "B" 1" = $100,000			Range "C" 1" = $1,000,000			Annual Average	
	Area	Loss	Ben.	Area	Loss	Ben.	Area	Loss	Ben	Losses	Benefits
Natural	15.31	612400	-	12.20	1,220,000	-	3.43	3,430,000	-	$5,262,400	-
400 YR.	5.51	220,400	392,000	0	0	1,220,000	0	0	3,430,000	220,400	5,042,000
500 YR.	4.62	184,800	427,600	0	0	1,220,000	0	0	3,430,000	184,800	5,077,600
1000 YR	2.45	98,000	514,400	0	0	1,220,000	0	0	3,430,000	98,000	5,164,400
2000 YR	1.23	49,200	563,200	0	0	1,220,000	0	0	3,430,000	49,200	5,213,200



EAST HARTFORD DAMAGE FREQUENCY
BASE AREA
1977 CONDITIONS
1977 STUDY
1977 PRICE LEVEL

PLATE NO 8